Arduino and MATLAB-Based Distance Relay System for Fault Detection in Underground Transmission Lines

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Abstract- This paper presents a smart and cost-effective solution for detecting faults in underground transmission lines using an integrated Arduino and MATLAB-based distance relay system. Underground cables are increasingly replacing overhead lines in urban networks due to safety and aesthetics, but locating faults in these cables remains challenging. The proposed system uses Ohm's law principles to estimate fault distances by measuring voltage drops and resistance changes during fault conditions. The Arduino microcontroller processes real-time analog data, while MATLAB is employed for simulation, visualization, and validation. This hybrid approach facilitates accurate fault location, reduces maintenance delays, and improves the reliability of power distribution systems.

Keywords: Underground cables, Distance relay, Arduino, Fault detection, MATLAB simulation, ADC, Transmission lines.

1. INTRODUCTION

The use of underground cables in urban power networks has gained popularity due to immunity from environmental effects and enhanced safety. However, fault identification is difficult due to limited accessibility. Conventional fault detection methods are time-consuming, expensive, and may damage insulation. This work proposes an intelligent fault detection technique using a microcontroller-based distance relay system, integrating Arduino and MATLAB for enhanced performance and ease of use.

2. SYSTEM DESCRIPTION

The proposed system includes:

- Voltage Sensors (Resistor Dividers) to sense voltage drops across cable segments.
- Arduino Uno, which serves as the processing unit.
- Relay Drivers (ULN2003A) and Relays, to isolate faulty sections.
- 16x2 LCD Display, LED Indicators, and Buzzer for real-time alerting.
- MATLAB/Simulink for fault modeling, distance estimation, and verification.

The system is designed to identify open circuit, short circuit, and earth faults using voltage drop patterns and calculate the approximate fault distance using resistance per unit length.

3. METHODOLOGY

3.1 Fault Distance Calculation

The system applies a fixed voltage at one end and measures current during fault. Using:

$$R = V / I$$

the fault resistance is calculated. Comparing this with the known resistance per unit length of the cable gives the fault distance:

$$\text{Distance} = R_{\text{Fault}} / R_{\text{standard}}$$

3.2 ADC Conversion

Arduino uses a 10-bit ADC with a resolution of 4.88 mV:

$$\text{ADC} = (\text{Input Voltage} / 5\text{V}) \times 1023$$

Sample voltages corresponding to 1–4 km was experimentally mapped to specific ADC values.

4. SOFTWARE DESIGN

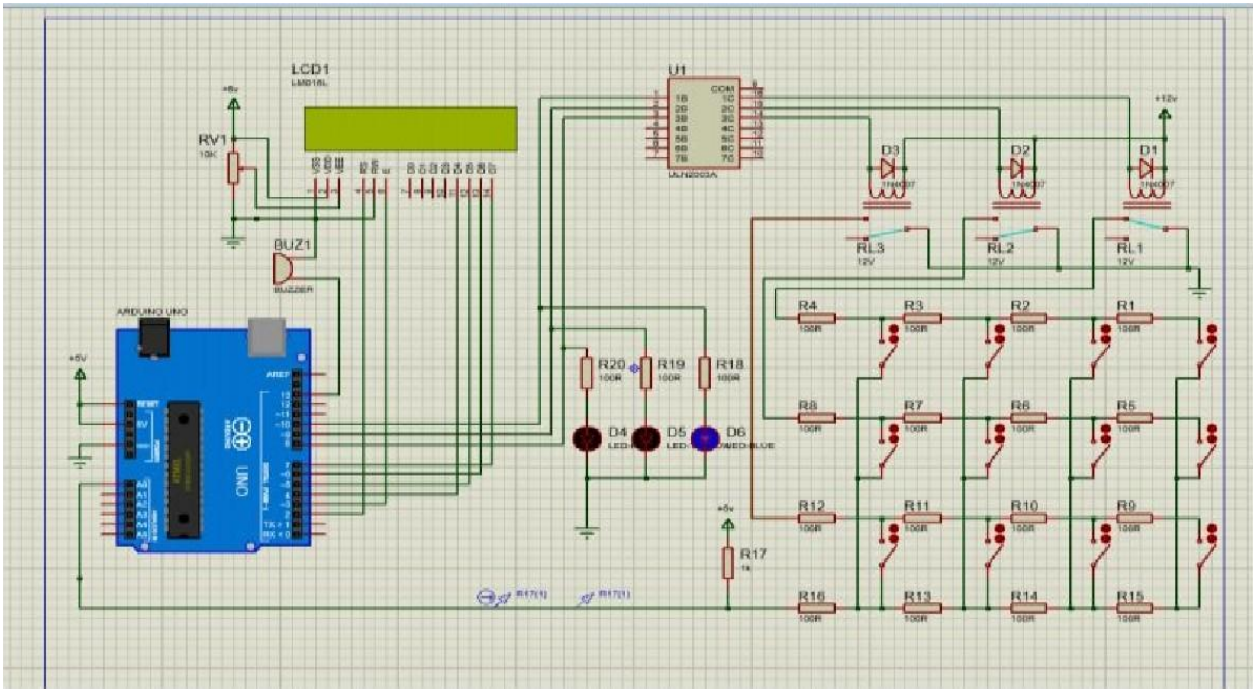
4.1 Arduino IDE

Code is written to read analog input from sensors, control relays and buzzers, and display output on LCD. The logic identifies the faulty segment based on ADC value ranges.

4.2 Proteus Simulation

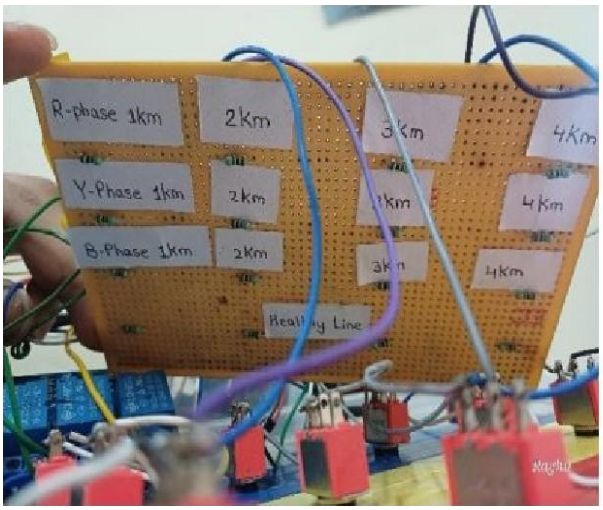
Proteus software is used for virtual simulation of hardware including Arduino, relays, sensors, and indicators. It helps validate circuit logic before hardware implementation.

Simulation Circuit:



5. HARDWARE DESIGN

The physical setup uses real components wired according to the simulated schematic. Manual fault switches are used to emulate different fault conditions on R, Y, and B phases. Each switch can simulate LG, LL, or LLG faults. The system automatically calculates and displays the distance to the fault in kilometers and triggers alerts.

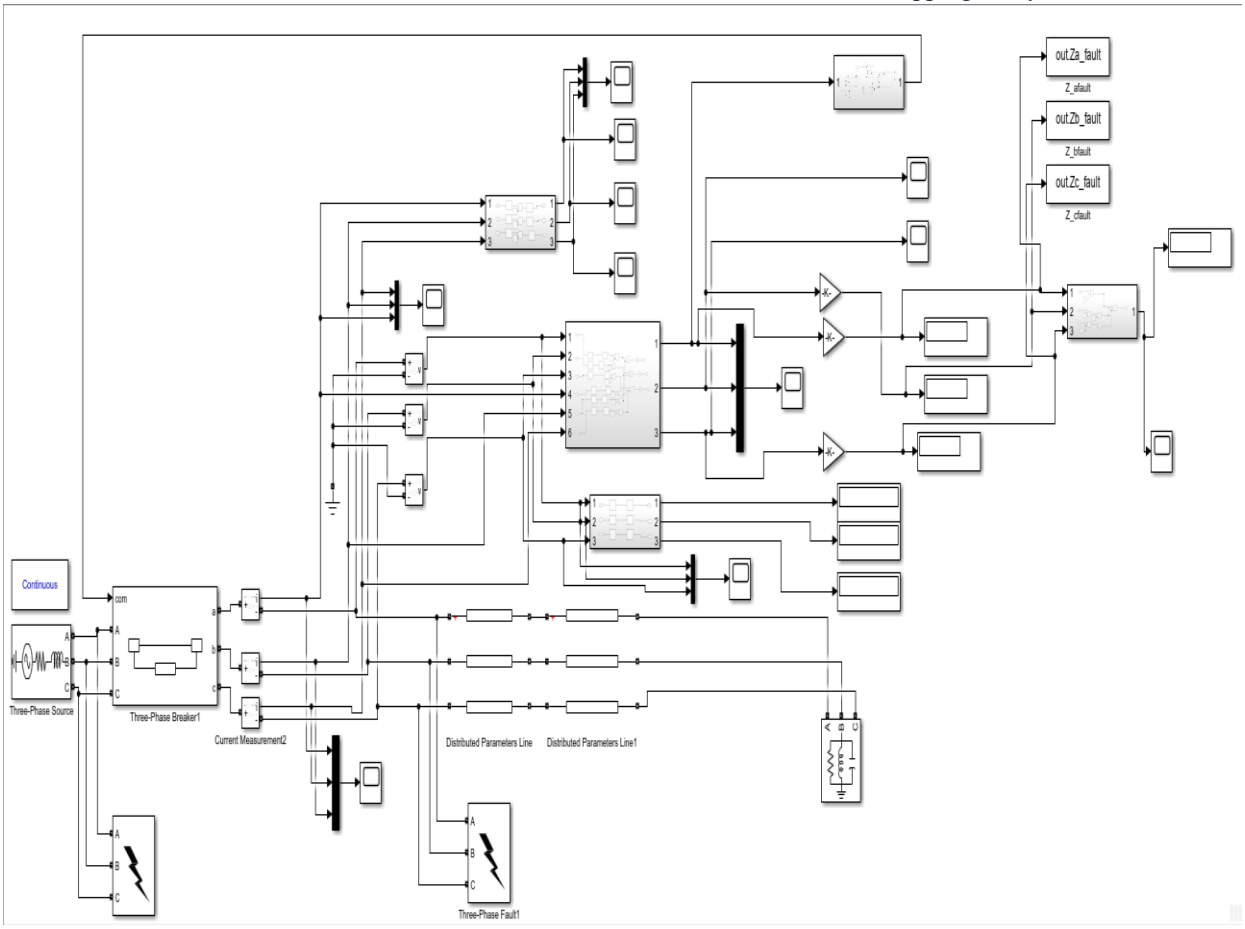


6. MATLAB-BASED DISTANCE RELAY SIMULATION

Using Simulink, a distance relay is modeled to calculate apparent impedance and make zone-based tripping decisions. Transmission line models are created with varying fault types and locations. The system divides protection into Zones 1, 2, and 3 based on the fault distance.

Simulation includes:

- Impedance measurement subsystem
- Zone logic subsystem
- Circuit breaker tripping subsystem



7. RESULTS AND ANALYSIS

7.1 MATLAB Simulation

- Case 1 (Zone 1 Fault): Fault at 40 km, relay trips immediately.
- Case 2 (Zone 2 Fault): Fault at 100 km, trip with delay.
- Case 3 (Zone 3 Fault): Fault at 160 km, backup trip logic triggered.

7.2 Proteus Simulation

- Displays correct fault location and trips respective relays.
- LEDs indicate phase-wise faults and buzzer alerts are functional.

7.3 Hardware Results

- Practical implementation showed high accuracy between calculated and actual fault distances.
- Minor variation due to resistance tolerance and ADC resolution.

8. CONCLUSION

The developed Arduino and MATLAB-based distance relay system effectively detects and locates faults in underground cables. The integration of hardware and

simulation improves fault detection accuracy, reduces repair times, and enhances power system reliability. This work demonstrates the feasibility of low-cost intelligent fault monitoring systems for real-world power distribution networks.

REFERENCE

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